DOCUMENT RESUME

ED 202 694 SE 034 931

AUTHOR Munby, Hugh
TITLE Thirty Studies Involving the "Scientific Attitude Inventory": What Confidence Can We Have in This Instrument?
PUB DATE Apr 81
NOTE 56p.; Paper presented at the Annual Meeting of the National Association for Research in Science Teaching (54th, Grossinger's in the Catskills, Ellenville, NY, April 5-8, 1981).

EDRS PRICE MF01/PC03 Plus Postage.
DESCRIPTORS *Attitude Measures; Elementary Secondary Education; *Evaluation; *Evaluation Criteria; *Evaluation Methods; Higher Education; Science Education; *Scientific Attitudes; Test Interpretation
IDENTIFIERS *Science Education Research; *Scientific Attitude Inventory

ABSTRACT

This paper reports an in-depth study of Moore and Sutman's Scientific Attitude Inventory (SAI) and of the 30 studies in which the instrument has been used. Findings from these 30 research studies reveal a wealth of information including: (1) conflicting results when similar treatments are used by different investigators; (2) varied values of the reliability of the SAI, some of which are ignored; (3) reporting of non-significant effects when they are not expected and vice versa; and (4) finding that some correlational studies provide discrepant information about the validity of the SAI. Although some of these results can be explained in terms of the conceptual validity of the SAI, it is concluded that there is some uncertainty of what is being measured by the SAI and that it needs reworking before it can be used with confidence. The paper concludes with some general concerns about attitude measurement and its place in science education research. (Author/JN)

Thirty Studies Involving the "Scientific Attitude Inventory":

What Confidence Can We Have in this Instrument?

Hugh Munby

Faculty of Education

Queen's University

April 1981

Paper presented to the Annual Meeting of the

National Association for Research in Science Teaching

Grossinger, New York, 1981

The Context for the Present Investigation

The investigation described here has two purposes. First, it attempts to assess the most popular instrument for measuring attitudes to science, the Scientific Attitude Inventory (Moore & Sutman, 1970), by examining the instrument itself and thirty of the studies in which it has been used. Second, an effort is being made here to show how it is possible to use a conceptual perspective in conjunction with the more typical psychometric ones as a means for identifying problems of validity and reliability in instruments of this type.

Possibly, the popularity of the Scientific Attitude Inventory (SAI) is reason alone for reviewing its performance over a decade of use. But the rationale for the present study goes further than this, and it is the task of this introductory section to show that there are grounds for having misgivings about all instruments of this type. More specifically, the need for a detailed study of a single instrument such as the Scientific Attitude Inventory became apparent as conclusions to a major study on attitude instruments in science education were being composed. So, to set the context for the present paper, it is important to describe briefly some features of that major study, although some of this has been done beforehand (Munby, 1980).

The major study was undertaken in the knowledge that there were available a large number of instruments purporting to measure attitudes to science, but that, as a research community, we might not know very much about their quality. So the question addressed in the major study was not "What do we know of learners' attitudes to science?" but "What confidence can we have in the instruments used to procure this knowledge?"

Sources of material in measuring attitudes to science were obtained primarily from retrospective machine searches of the literature, supplemented with earlier reviews, such as that of Ormerod and Duckworth (1975). It was originally planned to assess this literature over the ten-year period 1967-1977, but reviews made it possible to examine earlier materials, though with the full knowledge that the studies in this earlier period are not identified exhaustively. It happened that the decision to incorporate earlier material was a good one, for several research studies appearing between 1967 and 1977 used earlier instruments. Whenever such an instrument was cited, an attempt was made to locate all research in which that instrument had been employed.

Approximately 2,000 references were accumulated by these searches. A careful reading of the titles and abstracts led to the ready rejection of a large number of these since they either proved totally irrelevant or they had nothing substantial to add in the way of attitude measurement or research. (The latter category seemed largely to consist of exhortations about the importance of inculcating favorable attitudes to science and about the significance of measuring these.) It was decided that the very few masters theses could be excluded on the grounds first that they are generally not very accessible, and second that they are probably less thorough (and thus less useful) than doctoral dissertations--a judgment supported implicitly by the fact that none of the major reviews of research in the United States cites masters theses. Approximately 800 references survived this initial screening. The next step in sorting this material was the decision to categorize the remaining 200 instruments (and their research studies) according to the variables measured. Fifty-six instruments, regardless of titles, were identified as measuring attitudes to science, and those were the object of the intensive

scrutiny in the major study. (Other instruments measured such variables as attitudes to science careers, to science instructors, and to specific science issues.)

The context for the present investigation of the Scientific Attitude Inventory is completed by reviewing the principal findings of the major study. First, despite the size of this field (120 pieces of research used the 56 instruments plainly measuring attitudes to science, among the 200 instruments identified in the machine searches), there are no extensive reviews of the areas. Several selective reviews are available, yet, with the exception of Gardner's (1975), none is critical. Reviewing appears to be confined to mere reporting without reference to the quality of instruments used or of the research in general. Second, the field is strewn with a bewildering variety of conceptions of attitudes to science, as Figure 1 shows. Even among the 56 instruments chosen for investigation in the major study, one can readily detect a very wide-ranging interpretation of what sorts of targets are appropriate in the items of attitude measures: scientists, scientific courses, the difficulty of science, financial support of science, (governmental) control of science, scientific knowledge (laws, theories), science teachers, teaching science. All these are distributed throughout the instruments.

Neither is the ambiguity surrounding what constitutes a proper model of an attitude to science compensated by exactness in establishing the psychometric characteristics of the 56 instruments. Twenty-one of the instruments have no reliability information reported. Further, the reliabilities of 22 of the 35 whose reliability is known have been determined by the split-half technique--a measure of internal consistency during one performance, and not a measure of consistency from one performance to the next. Validity, too,

ATTITUDES TO SCIENCE

SCIENTIFIC ATTITUDES
(14 instruments)

Scientific Attitude

Scientific Processes

Scientific Cu; ·osity

ATTITUDES TO SCIENCE CAREERS (6)

Career Preferences

Occupational Interests

ATTITUDES TO SCIENCE
INSTRUCTION

Teaching Science (6)

Science Subjects and
Subject Preferences (27)

Science Interests and
Activities (20)

Attitudes to Science
Courses and Science
in School (24)

ATTITUDES TO SPECIFIC SCIENCE
ISSUES (1)

Energy Research

Reclaimed Water

ATTITUDES TO SCIENCE ITSELF (56)

Figure 1. Factors, variables, or attitudinal targets of instruments identified. (The following are not included: 30 semantic differentials, 5 projective devices, and 15 instruments which could not be obtained.)

is a problem. Twenty-two instruments have no validity information reported, or have validity assessed by a panel of judges. For only 29 instruments has any attempt been made to validate the scales psychometrically. Very few instruments have been validated by more than one psychometric technique, and only in nine cases is an attempt made to establish convergent validity. In addition, when the major study tackled the conceptual validity of tests by subjecting items to the conceptual analysis described below, it was found that most instruments contain a mix of items measuring knowledge about science affairs, value judgments, personal reactions (attitudes), and scientific or logical thinking. To be blunt, conceptual validity is clearly a major difficulty.

So, with very few exceptions, authors of instruments appear not to be taking all the steps that they might to assure us that their instruments may be used with confidence. In a curious sense, this may not be so great a problem, for only 21 of the 56 instruments are used more than once. Of course, this suggests that most instruments get developed for a one-shot investigation--a problem of a different sort for science education research. More troubling findings, though, come from examining cases in which an instrument is used in more than one study. Typically, later users take the instrument's reliability and validity on trust. That is, for 21 instruments there are 91 uses following the first use, unevenly distributed, and for only 7 of these instruments were reliabilities determined afresh (in a total of 14 of the 91 studies), while in only 2 studies was further information obtained about validities. Moreover, there was very little evidence that the authors had taken account of the performance of their instruments in later research and had revised them accordingly.

Not surprisingly, the principal conclusion of this major study was: "There are grounds for viewing research on the affective outcomes of science education with misgiving, simply because there seems little to be said of the instruments as to enlist our confidence in their use" (Munby, 1979, p. 273). It is against this backdrop that the investigation described below is conducted.

The Present Investigation

We begin the specific inquiry into the SAI with a description of the instrument, and then with a review of its reliability, of its performance in experimental studies, and of its relationship to other variables including its own subscales. At this point, the argument takes stock and suggests that we face a problem of conceptual validity, one which demands that some form of strict and disciplined attention be given to just what the items themselves are saying. The argument continues by developing a clue structure out of philosophical distinctions for examining the items. When the clue structure is used, some rather unexpected properties of the SAI are revealed.

The analysis then turns to compare its fruit with the empirical findings of a study by Nagy (1978). The patterns which emerge uphold the validity of the clue structure, and so support the contention that the SAI in its present form does not deserve our trust.

The SAI is a 60-item Likert-type instrument with a 4-point response scale (there is no neutral response), and is designed for high school students. Possibly the title of the instrument is somewhat misleading for, within the field of measuring attitudes to science, the term "scientific attitudes" is taken to represent those habits of mind generally associated with critical thinking and typically meant to characterize the mental processes of a scientist

at work. The scientist is thought to keep conclusions tentative, to weigh evidence carefully, to remain uninfluenced by the biases of his colleagues and himself, and so forth. Granted some of this appears in the SAI, yet an inspection of the instrument's subscales clearly demonstrates that the conception of attitude to science which underlies the instrument goes further than notions of critical and "scientific" thinking. The instrument's subscales appear in Figure 2. Each subscale contains 10 items which, for scoring, are evenly distributed into positive and negative. (The items comprising the SAI are appended.)

The face validity of the SAI was established by submitting an original collection of 112 items to a panel of judges and to a group of high school students. Construct validity was established by field testing the instrument with three groups of low ability tenth-grade biology students. One group was taught by the regular teacher, another was taught lessons to develop positive attitudes, and the third group was taught lessons to develop negative attitudes. Groups receiving instruction relevant to the instrument significantly outperformed the control group. The control group in this study provided a test-retest reliability of .934. Lastly, the instrument is reported to have a reading level below grade 8, according to the Dale list of 3,000 familiar words.

Reliability

As is evident from the title of this piece, the major study identified 30 studies in which the SAI had been used. Of these, only five reported new reliabilities for the instrument. The information available is given in Table 1. Naturally, the test-retest method provides a sounder index of the consistency of performance from one administration to the next, so the split-half technique

Sub-scale	Direction	Attitude Measured	Items
1	A	The laws and/or theories of science are approximations of truth and are subject to change.	7,10,23,53,56
	B	The laws and/or theories of science represent unchangeable truths discovered through science.	12,16,22,46,54
2	A	Observation of natural phenomena is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.	15,19,27,29,52
	B	The basis of scientific explanation is in authority. Science deals with all problems and it can provide correct answers to all questions.	2,3,11,39,43
3	A	To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of natural events, and willingness to alter one's position on the basis of sufficient evidence.	18,25,26,37,42
	B	To operate in a scientific manner, one needs to know what other scientists think; one needs to know all the scientific truths and to be able to take the side of other scientists.	4,5,8,38,51
4	A	Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.	6,32,33,34,47
	B	Science is a technology-developing activity. It is devoted to serving mankind. Its value lies in its practical uses.	14,24,41,44,50
5	A	Progress in science requires public support in this age of science, therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.	17,28,30,40,48
	B	Public understanding of science would contribute nothing to the advancement of science or to human welfare, therefore, the public has no need to understand the nature of science. They cannot understand it and it does not affect them.	9,13,31,36,58
6	A	Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work.	1,45,49,55,60
	B	Being a scientist or working in a job requiring scientific knowledge and thinking would be dull and uninteresting; it is only for highly intelligent people who are willing to spend most of their time at work. I would not like to do scientific work.	20,21,35,57,59

Figure 2. Subscales of the "Scientific Attitude Inventory".

Table 1

Reliability Values and Determinations for the SAI

Author	Publication Date	Reported Reliability	Type of Reliability
Moore and Sutman	1970	.934	Test-retest
McDuffie	1973	.648	Split-half
Popowicz	1975	.7966	Test-retest
Buckley	1976	.813	Test-retest
Novick and Duvdvani	1976(b)	.58	Cronbach α
Nagy	1978	.67	Split-half

is less useful. Typically, though, a split-half reliability (and Cronbach's alpha) can be expected to be higher than a test-retest, and two of the later determinations present exceptions to this rule of thumb. Of course, it could be expected that split-half reliabilities might fail to account for the six separate subscales, though the authors of the SAI proceed in the same fashion. From this information, we can at the least conclude that there are some questions to be answered about the SAI's reliability. We can go further. The present investigation has identified 10 doctoral dissertations undertaken between the publication of the SAI in 1970 and the citation in Dissertation Abstracts International of McDuffie's (1973) dissertation. In none of these 10 studies was any attempt found to examine the data for more information on the reliability of the SAI. After 1973, 13 studies use the SAI assuming the reliability to be .934 (the value reported by Moore and Sutman in 1970), and 4 of these are doctoral dissertations. Even if reliabilities were hard to compute we would be hard pressed to excuse these oversights, because sound results are inseparably tied to the soundness of the instrument producing the data. This is a useful perspective, of course, for looking at what happens when the SAI is used experimentally.

Some Experimental and Survey Studies

In this section, we report briefly on 17 studies in which the SAI is used as a criterion measure. Few clear patterns emerge.

College and University Students

Allison (1972) found no significant differences in the SAI (pre- and post-tests) when students enrolled in a semester chemistry course received different laboratory experiences. Nor did Costa (1973) find any significant attitudinal

differences among students having direct, vicarious, or written narrative laboratory experiences. However, Gunsch (1972) found a significant difference between two groups of freshman non-science majors taking either a lecture-demonstration course or a laboratory-oriented course, the difference favoring the latter. McDuffie (1973) compared students in an audiotutorial program with the population of college students and, using a stepwise multiple progression, found that subscale 6 of the SAI accounted for 22.5% of the variance, and subscale 3, 23.1%. Gadson (1976) compared the "thirteen-college curriculum program physical science course" with a traditional course, and obtained significant results favoring the new program. And Boes (1973) obtained significant gains among 32 students enrolled in "The Meaning of Science" course. Wilson (1975), using an anthology of articles on the understanding of science with 31 students, obtained significant differences on subscales 3 and 6 of the SAI over a control group of 20 students.

It is difficult to make a useful conclusion out of such a scattering of investigations. It would appear, though, if we can trust the SAI's reliability, that giving students curriculum content which is related to an understanding of science tends to improve scores on the SAI.

Preservice and Inservice Teacher Education

Riley (1975) found that when 90 student teachers were equally assigned to active inquiry, vicarious inquiry, and control group, no treatment effect could be discerned on attitude toward science, using the SAI--a finding which appears to support those of Costa (1973) and Allison (1972), noted above. Campbell and Martinez-Perez (1976) found that SAI scores did not predict performance in a science methods course.

Specific inservice efforts produce variable results. Moore (1975) sampled attitudes, using 40 items of the SAI, over a two year period: at the selection of a workshop, before the workshop, after the workshop, after one year, and after two years. While there was a significant gain from pre- to post-testing, scores declined to give a negative difference between the final two administrations. Giese (1971) compared SAI gain scores of teachers who received a five-week inservice course on the Intermediate Science Curriculum Study (ISCS) and found no significant difference. On the other hand, Lauridsen (1972) compared students of teachers who had undertaken an ISCS workshop with students of teachers who had not, and found a significant difference favoring the ISCS group; and Pinkall (1973) found a similar effect for fifth and sixth grade teachers and their students. All of which seems oddly contradictory.

School Curriculum and Teacher Effects

As before, results are variable when researchers attempt to find curriculum and program effects. Martinez-Perez (1973) found no difference in SAI scores between grade 6 and 7 ISCS and non-ISCS students. Yet, in a two year study, LaShier and Nieft (1975) found a significant relationship between cognitive achievement and scores on subscales 1 and 2 of the SAI for ISCS students, but not for non-ISCS students. Welch (1972) found significant differences between SAI scores of students in the PSNS course and students in other physical science courses. Martin (1972) compared students using the Blue, Green, and Yellow versions of BSCS and found no significant gains for any version. Popowicz (1975) found a significant difference favoring students in an experimental course of biology integrated with art. Lucas (1974) found that an instructional program at a science center made no difference to SAI scores, and that teacher and student attitudes did not correlate,

despite the contrary evidence suggested by Lauridsen (1972) and Pinkall (1973), above. Later, Lawrenz (1975), using a sample of 236 students, found no significant relationship between teacher and student attitude. All in all, a bewildering set of varying results is seen here.

School and Student Effects

Novick and Duvdvani (1976a) surveyed 684 tenth-grade students and found no significant attitude differences for type of school and type of curriculum. Similarly, Earl and Winklejohn (1977) compared the SAI scores of teachers in self-contained classrooms with those of teachers in cooperative settings, and found no significant difference. Lawrenz (1976) demonstrates that students' perception of the learning environment is related to SAI scores for biology students (23 per cent of the variance) and chemistry students (27 per cent of the variance). And Buckley (1976) found that teachers in towns served by an elementary school science specialist had a significantly more positive attitude to science than teachers not so served.

Covariates and Correlates of the SAI

Many studies, including those just reviewed, provide information about the covariates and correlates of the SAI. These are important, for they allow us to get a picture of what the test might be related to. In a sense, this gives us a psychometric slant on the validity of the SAI, then. Table 2 summarizes, in perhaps too brief a fashion, the findings when the SAI is tested alongside other instruments, and itself.

The picture of contrary, anomalous, or confusing results which we have already experienced tends to be reproduced in Table 2. For instance, the SAI correlates variously with TOUS: .52 (Wilson, 1975), and .03 and .36 (Boes, 1973).

Table 2

Relationship of SAI Scores to Variables and to Itself

Author(s)	Date	Variable	Relationship to SAI Scores
Boes	1973	Test on Understanding Science	Correlations of .03 and .36
Bowles & Boss	1974	Field-dependence (Thurstone Concealed Figures Test)	Field-independent Ss have significantly higher score than field-dependent Ss
Campbell & Martinez-Perez	1976	Basic Science Process Skills Integrated Science Process Skills Tennessee Self-Concept Scale	Correlation .54 Correlation .55 Correlation .76
Gieger	1974	Attitude to Science and Mathematics as School Subjects	Significant correlation
Giese	1971	Time Spent in Laboratory Management ISCS Teaching Behaviors	Significant correlation -.474 Significant positive correlation
LaShier & Nieft	1975	Cognitive Achievement for ISCS students	Significant relationship (Subscales 1 and 2)
Lauridsen	1972	Subject Preference	Correlations of .56 and [illegible]4
Lucas	1974	Stanford Achievement Test Attitude to Learning Science	No significant correlation Significant correlation
Martinez-Perez	1973	Self-concept Measures of Achievement	No significant correlations
McDuffie	1973	Nelson Biology Examination	Subscale 6 accounts for 22.5% variance Subscale 3 accounts for 23.1% variance
Moore	1971	Internal	No strong acceptance or rejection of any of the scientific attitudes assessed
Nagy	1978	Science Achievement Subject Choice	Small, significant correlations but clusters of SAI scores failed to correspond with subtests

cont'd

Table 2 cont'd

Author(s)	Date	Variable	Relationship to SAI Scores
Novick & Duvdvani	1976b	Internal, subscales	Acceptance of positive attitude did not correlate significantly with rejection of corresponding negative attitude, except Subscales 4 (-.156), 5 (.198), and 6 (.400)
Popowicz	1975	Coop. Science Test - Biology E.T.S.	Correlations of .213 to .250
Ward	1976	Science Achievement	Significant partial correlations
Wilson	1975	TOUS	Significant correlation (.57)
		Attitude: Science as a School Subject	Insignificant correlation (.32)

On one occasion it correlates quite highly with self concept, .76 (Campbell & Martinez-Perez, 1976) where earlier it did not (Martinez-Perez, 1973). Lauridsen (1972) found the SAI to correlate (.56 and .44) with subject preference and Lucas (1974) reports a significant relationship between the SAI and "Attitude to learning science," but Wilson (1975) found an insignificant correlation with "Attitude to science as a school subject." On the other hand, Gieger (1974) found a significant relationship between SAI score and attitudes to science and mathematics as school subjects. More perplexing is the variability in the relationship between the SAI scores and science achievement. The studies of McDuffie (1973), LaShier and Nieft (1975), and Ward (1976) point to a relationship. Popowicz (1975) reports a relationship, too, though it is small. On the other hand, Martinez-Perez (1973) and Lucas (1974) find no significant correlation with achievement.

Of course, such anomalies may be a function of a wavering reliability, or a fluctuating error term, to put the matter differently. But there are other possibilities. One of these is the relationships among the subscales of the SAI. Novick and Duvdvani (1976b) report that on only three of the six subscales did acceptance of a positive attitude correlate with rejection of the corresponding negative attitude, and one of these correlates negatively. To put this in perspective, we note that Moore (1971) found no strong acceptance or rejection of any of the attitudes assessed in a sample of similar size (672 students).

Possibly the most striking anomaly is that revealed by Nagy (1978) in a study which alerted us to possible difficulties in the field of attitude measurement, and which ultimately gave rise to the major study outlined at the beginning of the present argument. Nagy found significant though small

correlations between the SAI and measures of science achievement and subject choice. He then subjected items to a cluster analysis thus forming subtests, as distinct from the SAI's subscales. (Nagy calls the SAI subscales "groups.") Were the subscales of the SAI valid and independent of each other, we would expect a strong relationship between Nagy's subtests and the SAI's subscales. Nagy discovered little evidence of this independence, and plenty of evidence to show that the SAI's subscales do not correspond to unique clusters or subtests--a matter to be revisited later in this argument.

Taking Stock and the Way Ahead

For anyone interested in discerning clear, unambiguous, and usable findings in the science education research literature, this somewhat perfunctory sketch of the SAI's performance will be disquieting. It is not just that the SAI is offering up inconsistent results, a situation that could be repaired by carefully reassessing the instrument's reliability and proceeding from there. No, the matter strikes deeper: what we have just observed about the SAI can be explained quite adequately by suggesting that the instrument's validity is in doubt. If I am correct, which is to say that the studies cited in the preceding subsection are credible, then no amount of careful administrations of the instrument can repair the difficulty. Instead, we need to find a way of looking at the instrument itself to see if we can see a problem and what that problem might be.

Since the issue before us is one of conceptual validity, it is not at all unreasonable to suggest that we employ conceptual analysis. That is, an analytical perspective or clue structure is to be built which allows us to make sensible, useful, and well-grounded distinctions among the items in the instrument. The particular clue structure constructed and used here allows

us to see different statement types or statements with a different force in the items of the instrument. The clue structure itself is derived from analytical or philosophical distinctions which themselves are conceptually trustworthy.

The use of such a clue structure in science education research has several precedents in this kind of work. Roberts and Russell (1975) describe five studies in which clue structures are developed from philosophical considerations and then applied to educational phenomena in order to bring a new perspective to them. Further work in this genre of research is available in Munby, Orpwood, and Russell (1980). Here the general approach to developing philosophical tools for the systematic analysis of educational phenomena is developed fully in ten separate studies. Of course, a theoretical perspective for examining any sort of phenomena is just that: a theoretical perspective. There is no thought that the perspective represents the exclusive way to examine the phenomena in question. As a tool, though, the theoretical perspective or clue structure must be systematically derived, comprehensible to others, and useful in its application: it must enable us to see what we had not noticed beforehand.

The clue structure developed below was used in the major study of attitude instruments. The immediate task is to show its development. Next, the SAI is applied to the items of the SAI so we can see what is there to be seen.

Development of the Clue Structure from Conceptual Analysis

Distinctions of Statement Types

The following four items appear in the "Attitudes toward Science and Scientists" scale by Cummings (1970):

1. The majority of scientists are irreligious.

16. Scientific work is boring.

29. Government favoritism toward extraordinary scientific talent is undemocratic.

37. I wouldn't like to pursue a science research project.

Responses (on a five-point scale) to items such as these are intended to provide one with a measure of attitude to science, and there is no doubt that the items themselves speak generally to science-like topics. Yet a closer examination reveals that the items are very different in the sort of response demanded. That is, the character of the items differs so that one might expect the respondent to have to employ rather different mental resources to answer them. For instance, while item 16 calls for an emotional sort of reaction, item 1 seems to ask for some judgment about the truth of a claim about states of affairs. Similarly, item 37 calls for a judgment about preferred activities, while item 29 presents a statement which is true by definition and which leaves one wondering if it is testing an understanding of the term "undemocratic." Since these interpretations of the intent and meaning of the above items bear directly on the matter of construct validity, it seems useful to try to find a systematic clue structure for noting these differences. Such a clue structure is available in some basic distinctions among statement types in analytical philosophy and it is to this source that we turn for the first portion of the needed clue structure.

The primary source for the present clue structure is Wilson's (1967) categorization of statement types. Here, Wilson categorizes statements as follows:

a. Imperative and Attitude statements: For Wilson, these statements give commands and express personal wishes, hopes, desires, and fears.

"I hate science" would qualify as an attitude statement in this light.

b. Empirical statements: Empirical statements give information about the world, and are true or false depending on their correspondence with the world. "The majority of scientists are irreligious" qualifies as an empirical statement.

c. Analytical statements: These are similar to definitions and show how the meanings of words are related; they do not depend for their truth upon observations of the way the world is.

e. Metaphysical statements: This final category of statements is for those whose truth cannot be determined because we are unsure of how we should go about determining their truth. "God is love" is a metaphysical statement.

This categorization can be adapted to suit our purposes by making one deletion and by amalgamating two of the categories. It can be expected that very few if any items in an attitude instrument will be metaphysical statements, and so this category is deleted. (This decision is upheld by an analysis of instruments in the major study, which revealed no metaphysical statements among the 56 instruments examined.) Next, we may combine the empirical and analytic statements into a single category, for statement types can be thought of as cognitive. In this way, the preliminary clue structure for distinguishing items of attitude instruments contains three initial categories, as shown in Figure 3.

At this stage, then, the clue structure allows us to make useful comments about what any given attitude item is asking. If the item is an analytic or empirical statement, such as "Scientific explanations can only be made by scientists," then it is categorized as cognitive, with the recognition that

Attitudes to Science

A. Cognitive (Analytic and empirical)

B. Value (Judgment, commending, should, better)

C. Attitude (Emotional response, personal likes)

Figure 3. Preliminary version of the analytic clue structure.

the statement is possibly tapping the respondents' knowledge of matters related to science. Alternatively, if the statement is commending: "Scientists should not criticize each other's work," then it is categorized as a value statement calling for some judgment about what should be the case. Lastly, an item might be calling for an expression of personal likes or dislikes, such as "Science is fun," and "I would like to work in a scientific field"; then the statement is categorized as an attitude statement.

A preliminary examination of a small number of attitude instruments showed that some items could not be placed in any of these categories, simply because the items were measuring scientific thinking, often called "scientific attitudes" (though not to be confused with the content of the SAI's title). As mentioned earlier, these are thought to represent those habits of mind generally associated with critical thinking and typically supposed to characterize the mental processes of a scientist at work. Items of this type are clearly not seeking responses to questions as beliefs, feelings, and likes. For instance, Koslow and Nay (1976) list among the variables they measure "objectivity, willingness to change opinions, open-mindedness, questioning attitude" etc. (p. 153). Given that items of this sort appear in attitude instruments, the clue structure is enlarged to accommodate them, as follows.

Items measuring scientific attitudes do so in three quite distinct ways, giving rise to three more categories in the clue structure. The first two ways seem to test the possession of scientific attitudes, while the third way calls for a self-report.

The first category of items measuring scientific attitudes directly tests for those intellectual skills associated with science by posing questions of logic. An example is:

"The class discovered that magnets will attract objects made of iron or steel. A magnet will pick up Betty's hair clip. Conclusion: The clip must be made of iron or steel."

The second category consists of items which determine the respondent's disposition to reason "scientifically" or objectively. The following are examples:

"I would view with suspicion any findings reported by a scientist of another country."

"If a famous scientist and an unknown scientist disagree, we should accept the view of the famous scientist."

The third category in this portion of the clue structure classifies items which appear to ask the respondent to make a self-report on his or her scientific attitudes. Examples are:

"Logical thinking plays a large part in my life."

"I don't have the intelligence for a successful scientific career."

When these categories are added to the clue structure, it is expanded to six categories, as shown in Figure 4.

In this form, the clue structure offers some immediate usefulness to the reader. For instance, we can judge whether an attitude scale constructed as a five-point Likert scale possesses the characteristics which Likert wished this type of instrument to exhibit. Likert argues that it is essential that all statements be expressions of desired behavior and not of fact (Likert, 1967). Using the language of the clue structure, we would expect items of a Likert scale to be value items, and not cognitive items. To take an example, 29 of the 60 items comprising Brown's (1975) "Attitude to Science Scale" are cognitive items, and only 10 items are value items. Probings of this sort are possible with the clue structure developed here.

Attitudes to Science

A. Cognitive (Analytical and empirical)

B. Value (Judgment, commending, should, better)

C. Attitude (Emotional response, personal likes)

Scientific Attitudes

D. Test of Possession -- Intellectual Skills

E. Test of Possession -- Dispositions

F. Self-Report Dispositions

Figure 4. Second version of the analytic clue structure.

(It is worth noting that, while the clue structure itself contains the word "attitude" as one of its categories, this is not to imply that items classified as cognitive or value are not useful for measuring attitudes. The word "attitude" in the clue structure simply conforms to Wilson's terminology.)

Distinctions from Philosophy of Science

Earlier work by this writer has suggested some interesting possibilities for exploring further the conceptual validity of attitude instruments. Munby (1973) derived a clue structure from considerations in the philosophy of science which, when applied to science teaching, showed quite plainly that quite different views of the nature of science are conveyed in teaching discourse. Later work (Munby, 1976) suggests that similar measures about science are implicit in textbooks. It is quite possible that similar views are conveyed wittingly or unwittingly in the language of attitude items to the effect that they might not be measuring attitudes to science, but rather are assessing the respondents' philosophical view of the nature of science which, by definition, is not attitudinal but largely cognitive, since it is based upon knowledge and understanding of science. Additionally, of course, if an attitude item contains an implicit view of science, there is always the possibility that in responding to the attitude item one is bound to commit himself to this view of science. For these reasons it was decided that the present clue structure be enlarged by adding the writer's previous clue structure for detecting views of science.

Two views of science are detected using this clue structure, which appears in Figure 5. These views of science which were originally derived from the work of Nagel (1961) and others are Realism and Instrumentalism. For Realism, scientific theories and explanations are taken to be true descriptions of the

REALIST:

a. Theories are stated as if they have the same logical status as observation statements.

b. "Scientific objects" (postulated entities) are talked about as if they have the same ontological status as common-sense objects of perception. They have a physical reality.

c. Science presented as the only acceptable way of describing or explaining the world of phenomena.

d. Science spoken of as superior to alternative explanatory modes.

e. Past theories are presented as false.

f. Lapsed "scientific objects" given as inaccurate accounts of reality.

g. The potential of science for explaining or describing is given as unlimited.

h. That a model, law, theory, or convention is being used is not signalled to pupils.

i. A model, law, theory, or convention is invoked as a description of phenomena.

INSTRUMENTALIST:

a. Theoretical and explanatory statements are stated as if they have a logical status different from that of observation statements.

b. "Scientific objects" presented as having a different ontological status from common-sense objects of perception. They are postulated entities.

c. Science presented as one way of explaining the world of phenomena.

d. Science spoken of as in competition with alternative explanatory modes.

e. Past theories presented as inadequate.

f. Lapsed "scientific objects" given as inadequate explanatory devices.

g. The potential of science for explaining and describing is given as limited.

h. That a model, law, theory, or convention is being used is signalled to pupils.

i. A model, law, theory, or convention is invoked as an explanation of phenomena.

Figure 5. Munby System for detecting views of science.

world, and scientific constructs are thought to have an ontological status similar to that of commonsense objects of perception. For Instrumentalism, though, scientific theories and explanations are instruments for ordering perceptions, and scientific constructs are postulated entities. The clue structure for detecting these views is derived from these two positions.

The present clue structure for analyzing attitude instruments incorporates the view of science clues by the inclusion of categories for the two views of science and for whether these views are implicit or explicit. The result of this union appears in Figure 6. Some examples of items containing explicit or implicit views of science show again some of the complexities involved in establishing the construct validity of scales to measure attitudes to science. Consider item 22 of the SAI:

"Scientists discover laws which tell us exactly what is going on in nature."

On the face of it, this item is a cognitive item asking whether or not the respondent thinks that scientists discover laws of a certain type. The item, though, can be seen quite readily to be saying something important about the type of law which a scientist may discover. The statement conveys the Realist view, implicitly then, that the laws are true statements about the world, and not conceptual conveniences subject to change and limitations. The item "Statements are not accepted as scientific knowledge unless they are absolutely true" is also a Realist item, but in this case the view of science is being put forward explicitly, and the item is directly tapping it.

Similarly, the view of science in the following item is put forward explicitly, though in this case it is Instrumentalist: "The scientist knows that ideas will change if new facts are found." The message here is that

Clue Structure Name	Coding
Attitudes to Science	
A. Cognitive (Analytic and empirical)	Cog
B. Value (Judgment, commending, should, better)	Val
C. Attitude (Emotional response, personal likes)	Att
Scientific Attitudes	
D. Test of Possession -- Intellectual Skills	TPI
E. Test of Possession -- Dispositions	TPD
F. Self-Report -- Dispositions	SRD
View of Science	
G. Explicit -- Instrumentalist	Exp I
H. Explicit -- Realist	Exp R
I. Implicit -- Instrumentalist	Imp I
J. Implicit -- Realist	Imp R

Figure 6. Clue structure for analyzing item meanings.

ideas are not more than ways of conceptualizing facts. The item "Construct a theory before you try to solve a problem" conveys a major thought about how to proceed in science; yet implicit in this item is the view that theories are constructed, so the view of science implicit here is Instrumentalism.

The clue structure also incorporated some elementary considerations from the area of test item writing, under the heading "Additional Item Characteristics." Listed here are: trick questions, confusing formats (e.g., double negatives), excessively difficult items, grammatically incorrect items, items containing spelling errors, and ambiguous or double-barreled items.

Estimating the Reliability of the Clue Structure

As we have already noted, a clue structure must not only be thoroughly grounded but it must also be usable in a way that yields similar results when applied by different people. In a sense, this criterion is not unlike the psychometric notion of reliability and it will be referred to in this way. Strictly, though, this criterion speaks more to the objectivity of the device or the inter-user agreement when it is used. The reliability of part of the clue structure is already known with some confidence. Munby and Wilson (1978) used the Munby System in a convergent and discriminant validity study and obtained a correlation of .97 when 47 science lessons were analyzed by two independent coders.

Estimating the reliability of the remainder of the clue structure proved to present something of a problem, for a number of reasons. As a consequence, reliability information while available is sparse, and undeniably restricts the confidence one might otherwise have in the use of the clues. During the construction of the clue structure, and the trials at making the clues (and their instructions for use) suitable to the task, a small number of informal

attempts at obtaining an interobserver agreement were undertaken. At one point, an agreement of 93 per cent was obtained between two coders for the 60 items of the SAI. Following this, it was only possible to conduct reliability estimates on two instruments, Meyers' (1975) and Redford's (1974). These estimates were from coding by the present writer and a graduate student who had not been trained in the use of the clue structure to any extent, so the results (73 per cent and 76 per cent respectively) probably represent a conservative estimate of the clue structure's reliability.

Using the Clue Structure

Each item of the SAI is coded according to the clue structure, using the code appearing in Figure 6. Each item is coded with one of Cog, Val, Att, TPI, TPD, SRD. Each item may also be coded to note the presence, implicit or explicit, of a view of science. Accordingly, item 13 "Most people are not able to understand the work of science" is coded "Cog," whereas item 22 "Scientists discover laws which tell us exactly what is going on in nature" is coded "Cog, EXP R" for there is the clear statement that science has the potential for uncovering reality and truths. Some items need to be coded twice because they are double-barreled. Item 48 is a case in point. The first part of this item, "Every citizen should understand science," is "Val," but the second part "because we are living in an age of science" appears more as a cognitive item. This sort of analysis is represented as "Val/Cog," the first code referring to the first part of the item, and the second to the second part.

Analyzing the SAI

Quite clearly, use of the clue structure demands a certain amount of judgment, and judgment can vary. Accordingly, it was decided that the best

approach to sharing this method of conceptually examining the SAI was to use the analysis contained in the report of the major study (Munby, 1979) and a fresh analysis, completed this January. When the two analyses are set beside each other, they reveal some differences. This turns out to be both a strength of the analytical technique and an index of its weakness. The latter is obviously the case; use of the clue structure depends on judgments and these may not be reliable. The strength, though, may be less obvious. If we examine an item which has been coded in two ways we see that the more we peer into the item to resolve its meaning, the more we are conscious of our uncertainty about what the item is driving for. In short, then, our concerns for the conceptual validity of the SAI appear to be sharpened when we encounter difficulties in applying a conceptually consistent clue structure to its items.

In the analyses of 1979 and 1981 the items were examined in the order in which they appear in the SAI itself (appended). Next, a table similar to Table 3 was constructed and the analyses transferred so that comparisons could be made between them and between the a priori subscales of the instrument. The 1979 analysis is presented in full. Only when the 1981 analysis differed is this indicated, so that blank spaces represent congruence between the analyses. The analyses of items in each subscale are discussed below seriatim.

<u>Analysis of Subscale 1</u>

A: The laws and/or theories of science are approximations of truth and are subject to change.

B: The laws and/or theories of science represent unchangeable truths discovered through science.

There is a very clear correspondence between the instrumentalist's view and

Table 3

Analyses of the SAI Items by Subscale Membership

Sub-scale	Item	1979 Analysis	1981 Analysis	Sub-scale	Item	1979 Analysis	1971 Analysis
1	7	Cog, Exp I	TPD, Imp I	4	6	Cog, Exp I	
	10	TPD, Exp I	Cog		14	Cog	Val
	12	Cog, Exp R			24	Val	
	16	TPD, Exp R			32	Val, Imp I	
	22	Cog, Exp R			33	Val, Imp I	Val
	23	Cog, Exp I			34	Val, Exp I	Val
	46	TPD, Exp R	Cog		41	Cog	Val
	53	Cog, Exp I			44	Val	
	54	TPD, Exp R	Cog		47	Cog, Exp R	
	56	TPD, Exp I	Cog		50	Val	
2	2	Cog, Exp R	Imp R	5	9	Cog	Att
	3	Cog			13	Cog	
	11	Cog, Exp R	Imp R		17	Cog	
	15	Cog, Exp R	Imp R		28	Val	Cog
	19	Cog, Exp I	Imp I		30	Cog	
	27	Cog	TPD		31	Cog	
	29	Cog, Exp I			36	Cog	
	39	Val			40	Val/Cog	
	43	Cog	Cog, Imp I		48	Val/Cog	
	52	Cog	Val		58	Cog	Val
3	4	Val, Exp R	Imp R	6	1	Att	
	5	TPD	Val		20	Att	
	8	TPD, Exp R	Cog, Imp R		21	SRD	Cog, Exp R
	18	Cog	TPD, Imp I		35	Att/Cog	
	25	Cog, Exp I	Imp I		45	Att	
	36	Val, Exp I	Imp I		49	Att/TPD	
	37	Val, Imp I	Imp I		55	Att	
	38	Val			57	Cog	
	42	Val			59	Cog/Att	
	51	Val			60	Att	

the intent of this subscale, and it is unsurprising that the two analyses point to half the items being "Exp I" (with one inconsistency) and half "Exp R". Thereafter, there is less clarity, for the 1979 analysis suggests that half of the items are cognitive and so measure knowledge, whereas the other half is seeking test of possession of the disposition to think in a "scientific way." The 1981 analysis suggests that all but two items are cognitive. Item 16, "When something is explained well, there is no reason to look for another explanation," seems to ask if we think critically or scientifically, and this is quite different from asking if we subscribe to one or another philosophical view of the nature of science (or reality). Item 22, however, ("Scientists discover laws which tell us exactly what is going on in nature"), is clearly not asking us to reveal our critical abilities; instead it directs attention to what we think might be the relationship between scientific laws and reality.

This very plain difference between the approaches taken in this subscale to differentiate between instrumentalism and realism may well be responsible for poor performance of the instrument in research studies.

Analysis of Subscale 2

A: Observation of natural phenomena is the basis of scientific explanation. Science is limited in that it can only answer questions about natural phenomena and sometimes it is not able to do that.

B: The basis of scientific explanation is in authority. Science deals with all problems and it can provide correct answers to all questions.

As we enter the analysis, it is important to note that the focussing statement describing this subscale is cognitive, according to our clue structure. That the analyses point in this direction is consequently a useful index of consistency. Item 15, "Scientists cannot always find the answers to their questions," makes a claim about the world to which the answer is yes or no--

it is a cognitive item. Yet, item 39, "Before one can do anything in science, he must study the writings of the great scientists," has a prescriptive force to it, as do statements judged to be value statements--a measure of what we think ought to be done as opposed to what is the case. Item 27, "Looking at natural phenomena is a most important source of scientific information," is analyzed ambiguously, though its fit to the subscale is unquestionable. This is not so straightforwardly the case with 5 of the subscale's 10 items, for we see Realist and Instrumentalist coding in Table 3. Interestingly, analyses of these items diverge significantly on the question of whether or not a view of science is given implicitly or explicitly here. As it happens, this issue pales in the light of the question, "What are items measuring view of science doing in this subscale?" Some examples are helpful. Item 15, just cited, carries the implication that science has the potential for answering (really) all questions, a message plainly echoed in item 2, "Anything we need to know can be found out through science." The manner in which philosophical views of science enter these items is strongly suggestive of an anomaly in the conceptual distinctiveness of subscales 1 and 2, if not in the conceptual validity of the instrument itself.

Recalling our brush with empirical findings, above, we might draw attention to the study by LaShier and Nieft (1975) which finds a significant relationship between cognitive achievement and subscales 1 and 2 for ISCS students. Possibly ISCS encourages an instrumental view, one which can be detected by both of these subscales, as the conceptual analysis has shown.

<u>Analysis of Subscale 3</u>

A: To operate in a scientific manner, one must display such traits as intellectual honesty, dependence upon objective observation of

natural events, and willingness to alter one's position on the basis of sufficient evidence.

B: To operate in a scientific manner, one needs to know what other scientists think; one needs to know all the scientific truths and to be able to take the side of other scientists.

As above, we may begin our approach to analyzing the items of subscale 3 with an attempt to analyze this description of the attitude which is to be sampled here. The statement appears to offer a view about what should be the case, and in this respect the statement is a value statement. There is, of course, the reasonable inference that if I make this statement, then I myself am disposed toward intellectual honesty, etc. Here in the clue structure we can see that a fine line separates "value" from "test of possession--disposition." An example from the SAI shows this. Item 26, "A good scientist doesn't have any ideas he is not willing to change," seems more clearly seeking to know how we might judge a scientist (a value statement) than it is seeking to see if we are disposed to changing ideas we harbor, a test of possession--disposition (TPI). An alternative perspective is available in item 5, "It is useless to listen to a new idea unless everybody agrees with the idea," appears to sample the way in which my receptivity to a new idea is influenced by others' views of it. In this case, the item _is_ a test of possession--disposition.

Generally, the analyses here point to the items here as value items, and that would appear to be in order were it not for the fact that between 5 and 7 of the items are found to convey philosophical positions about the nature of science, in much the same way that we witnessed this happening in subscale 2. For example, the wording of item 26, just mentioned, contains the presumption that ideas (theories and the like) are the sorts of things that can be changed--

an instrumental leaning. The view of science conveyed by item 8 is similarly transparent: "If one scientist says a theory is true, all other scientists will believe him" implies that theories are spoken of as true or false, which is clearly realist.

Here, the analysis shows that subscale 3 indeed has the potential for picking up the attitude intended. Further, though, the analysis shows it can pick up more than this--a conceptual difficulty which can lead to problems when interpreting responses to the items in experimental or evaluative situations.

Analysis of Subscale 4

A: Science is an idea-generating activity. It is devoted to providing explanations of natural phenomena. Its value lies in its theoretical aspects.

B: Science is a technology-developing activity. It is devoted to serving mankind. Its value lies in its practical uses.

Analysis of items in this subscale suggests that they are largely value statements. The 1979 analysis finds four cognitive items, while this is reduced in the 1981 analysis. The impression, then, is that the subscale does seek preferences, judgments, and commendations. For example, item 44 states, "An important purpose of science is to help man to live longer," and thus asks us to judge if this is important as a purpose of science. Some of these items are harder to analyze. Table 3 shows item 14 to be among these: "Today's electrical appliances are examples of the really valuable products of science." Here the range of "products" clearly affects the response, as does one's understanding of the extent to which such a device is a product of science. The definitional difficulty may well account for the coding difference.

The presence here of items which implicitly or explicitly speak of philosophical views of science ought not to be overlooked. Item 34's claim, "Ideas are one of the more important products of science," implicitly suggests that laws and theories are not to be considered as anything but ideas--a message which is instrumental in character, while item 47, "Science is devoted to describing how things happen," carries the realist view that laws and theories are simply descriptions of what is really out there in the world of nature. This continuing thread of realism or instrumentalism throughout the instrument may well act as a conceptual contaminant of its validity.

Analysis of Subscale 5

A: Progress in science requires public support in this age of science, therefore, the public should be made aware of the nature of science and what it attempts to do. The public can understand science and it ultimately benefits from scientific work.

B: Public understanding of science would contribute nothing to the advancement of science or to human welfare, therefore, the public has no need to understand the nature of science. They cannot understand it and it does not affect them.

The analysis of this subscale is abundantly clear: the items are largely cognitive, with those that are not coded as such in one analysis being coded that way in another analysis. The implication of this is evident from a single example. Item 31 reads, "Scientists do not need public support, they can get along quite well without it." The more one knows of the costs of research and development, the more it is apparent that this statement is false. Accordingly, the basis upon which one draws to answer this question is knowledge, and not just knowledge about science, but knowledge of a very specific kind.

So, unless this kind of knowledge is made explicit in a science curriculum, we would hardly expect to see a change from pre-test to post-test in scores on such items. This would suggest that the place of cognitive items like this in an attitude scale may provide a distorted picture of what a learner's attitude is. Subscale 5 of the SAI may not be picking up attitudes but a measure of knowledge or ignorance about science affairs.

It is particularly difficult to know how to assess this number of cognitive items in an attitude scale in the light of Likert's argument that statements be expressions of desired behavior and not of fact (Likert, 1967).

Analysis of Subscale 6

A: Being a scientist or working in a job requiring scientific knowledge and thinking would be a very interesting and rewarding life's work. I would like to do scientific work.

B: Being a scientist or working in a job requiring scientific knowledge and thinking would be dull and uninteresting; it is only for highly intelligent people who are willing to spend most of their time at work. I would not like to do scientific work.

Our expectation here is that items of this subscale would be coded as "attitude" since the statement calls up the phrases "emotional response" and "personal likes" noted in the clue structure. To a large extent this seems to be the case, as exemplified by item 20 "The day after day search for scientific knowledge would become boring for me." Item 21, however, confounds the view: "Scientific work would be too hard for me," which is coded as a self-report of disposition, presumably because the item appears to invite an inspection of one's ability to work scientifically just as much as it invites an emotional reaction. So subscale 6, too, is not without its conceptual problems.

Conceptual Analysis of the SAI and the Nagy Study

To this point we have seen that, when the clue structure is applied to the subscales of the SAI, conceptual confusions about their validity are revealed. Of course, the application has not been without its own problems, but I contend that there are sufficient grounds here for judging the SAI to be conceptually doubtful, if not very weak. Nevertheless, it might still be pressed that the analysis itself is too shaky to fasten down the issue so finally, and for this reason it is useful to revisit the Nagy study. Nagy (1978), as mentioned beforehand, correlated SAI scores with subject choice and achievement, partialled out intelligence, and then performed a cluster analysis which resulted in the formation of clusters that failed to correspond to the subscales of the SAI, as given by its creators. Nagy constructed subtests out of these clusters, and at the same time discarded items which failed to demonstrate empirically that they belonged. (Only clusters with KR-20's greater than .50 were reported.) Table 4 reproduces Nagy's results and includes the analyses of the items using the clue structure. There are interesting patterns to be discerned. Nagy's subtests 1 and 2 (cluster 1) is composed predominantly of attitude items, and they come from SAI subscale 6. Cluster 2 and the early part of cluster 3, Nagy's subtests 3 and 4, come from SAI subscales 5 and 4, and are cognitive and value items. Thereafter, as the subscale membership of the clusters become less distinctive, so do the item types. This trend suggests that the clue structure's inherent logical distinctions can be related to empirical findings.

This claim is upheld most strikingly in Table 5, where items discarded during formation of Nagy's subtests are presented beside their coding according to the clue structure. Of the 26 items discarded on sound empirical grounds,

Table 4

SAI Items in Nagy's Clusters and Subtests, With Their Analyses

Nagy Cluster	Item	1979 Analysis	1981 Analysis	Nagy Subtest	SAI Subscale
1	1	Att		1	6
	21	SRD	Att		6
	55	Att			6
	20	Att	Imp R	1 + 2	6
	35	Cog/Att			6
	45	Att			6
	49	TPD/Att			6
	59	Cog/Att			6
	60	Att			6
	9	Cog	Att	Dropped	5
2	28	Val	Cog	3	5
	30	Cog			5
	31	Cog			5
3	14	Cog	Val	4	4
	41	Cog	Val		4
	44	Val			4
	50	Val			4
	7	Cog, Exp I	TPD, Imp I	5	1
	17	Cog			5
	19	Cog, Exp I	Imp I		2
	27	Cog	TPD		2
	36	Cog			5
	40	Val/Cog			5
	42	Val	TPD		3
	47	Cog, Exp R			4
	48	Val/Cog			5
	52	Cog	Val		2
	56	TPD, Exp I	Cog		1

Table 4 (cont'd)

Nagy Cluster	Item	1979 Analysis	1981 Analysis	Nagy Subtest	SAI Subscale
4	4	Val, Exp R	Imp R	Dropped	3
	13	Cog			5
	43	Cog	Imp R		2
5	5	TPD	Val	6	3
	11	Cog, Exp R	Imp R		2
	38	Val			3
	39	Val			2
	46	TPD, Exp R	Cog, Exp R		1
	58	Cog	Val	Dropped	5

Table 5

Items of the SAI Dropped From Nagy's Subtest Formation,

and Their Analyses

Subscale of SAI	Item	1979 Analysis	1981 Analysis
1	10	TPD, Exp I	Cog
	12	Cog, Exp R	
	16	TPD, Exp R	
	22	Cog, Exp R	
	23	Cog, Exp I	
	53	Cog, Exp I	
	54	TPD, Exp R	Cog
2	2	Cog, Exp R	Imp R
	3	Cog	
	15	Cog, Exp R	Imp R
	29	Cog, Exp I	
3	4	Val, Exp R	
	8	TPD, Exp R	Cog, Imp R
	18	Cog	TPD, Imp I
	25	Cog	TPD
	26	Val, Exp I	Imp I
	37	Val, Imp I	
	51	Val	
4	6	Cog, Exp I	
	24	Val	
	32	Val, Imp I	
	33	Val, Imp I	Val
	34	Val, Exp I	Val
5	9	Cog	Att
	58	Cog	Val
6	57	Cog	

19 carry implicit or explicit messages which tie the items to either the realist or instrumentalist view of science. This does not establish unequivocally that the SAI's conceptual validity is contaminated by the philosophical views of science carried by some of its items, but it does compel us to take seriously the claim that the instrument's validity is highly questionable. And it is to be remembered that this claim was initially arrived at independently of revisiting the Nagy study.

The Findings and the Need for an Analytical Methodology

It is helpful to retrace the journey taken so far. The findings of the major study which were reported above suggest that not only is the field of measuring attitudes replete with instruments but that these instruments are used in a rather cavalier fashion, without heed to their reliability and validity.

The mixed findings obtained from the most popular instrument, the SAI, underscore the early and smaller claim of this argument that the SAI, if not the field, may be beset with conceptual difficulties. At this point, a coherent and consistent clue structure, developed from philosophical considerations, is constructed and aimed at the SAI with illuminating effect: the instrument's subscales have problems. Finally, this judgment is unexpectedly reinforced when the items grouped according to Nagy's findings reveal patterns when analyzed with the clue structure. The SAI, we must own, needs conceptual rebuilding.

It is all too easy to make such a statement and then pass it over without giving time or thought to what might be involved in this conceptual rebuilding. At the root here, of course, is concern for useful and coherent ways of conceptualizing "attitude to science." We have already seen in Figure 1 the wide range of meanings which the science education research community seems to have attached to the idea of attitude to science. Yet, the variety of conceptions

does not end here, for even among the 56 instruments selected for detailed examination in the major study one can readily detect a very wide-ranging interpretation of what sorts of targets are appropriate in the items of attitude measures. Such terms as scientists, scientific courses, the difficulty of science, financial support of science, control of science, scientific knowledge, applications of science, science teachers, reading science, and many more appear in a proliferation of target concepts which signals the ambiguity presently surrounding a conceptualization of attitude to science.

A very large quantity of the findings that we have listed above for the SAI are reflected in the other instruments examined in the major study and point us in the direction of questioning the concept "attitude to science." So it seems appropriate here to initiate the needed questioning by mapping some of its troublesome features.

One problem anent to measuring attitudes to science is that the very idea of science might be ambiguous. We can easily see how the concept "science" may be taken to refer to the science courses and lessons taken in school and college and the substance of those lessons. It is not that such lessons do not portray science, but that they probably give science experiences to youngsters which are quite different from those of an historian or philosopher of science. Of course, it is equally probable that some will view science in the professional sense, and so the concept conjures up meanings related to careers in science. These differences in how meaning is attached to concepts may be avoided if instruments are designed strictly with subscales or entire scales given clearly to the target concepts, such as science in school, a science career, and so forth. In fact, some framework similar to the one appearing in Figure 1 could constitute the bases of at the least

distinguishing the varieties of subscales from one another. While all this seems to be a necessary part of reducing the ambiguity of the target concept "science" it may not readily extinguish it, for the ambiguity extends beyond these interpretations. Science, it could be argued, is so much a part of western thinking that its meaning and its implications for society might get lost behind the rather more obvious and superficial (if not newsworthy) ways in which its presence is felt. We see the impact of science on society and nature very clearly when we consider nuclear weaponry and oil-slicks. Less prominent, though significantly ubiquitous, is the impact of science on our clothing, foodstuffs, and on our thinking, so that we tend to picture our environment as it is painted by science. The extent of science's permeation is beyond the scope of the present discussion. Suffice it to say that it may be difficult to get at a person's attitudes to science if he or she is not wholly aware of the extent to which science is a part of his or her intellectual and physical life.

Any inquiry directed at unpacking the concept of "attitude to science" must contend with this sort of problem. It must also look at the educational appropriateness of making the possession of "positive attitudes to science" so important an objective that it has become an obviously acknowledged source for some of the measuring equipment wielded by researchers and evaluators in science education. The call here, then, is that we attend to whether getting someone to <u>like</u> science or "feel positive" about it is an educational objective or an objective that is more properly characterized as miseducational or indoctrinaire (if indeed the latter is not subsumed by the former). Accordingly, we have to ask what business it is of science education to promote a liking for science and science-related matters, and why science education

ought not to restrict itself to bringing about awareness, understanding, and knowledge. Again, it seems that any fresh conceptualization of "attitude to science" undertaken for science education must attend to the conceptual relationships that "attitude to science" has with education and not, say, to public administration, to the study of political movements, or to the examination of social expression, each of which has its own (disciplined) conceptual relationships.

A possibly useful starting point might be found in Klopfer's (1976) structure for the affective domain in science education. Yet this structure itself seems not to consider the philosophical and ethical problems just noted. For instance, an example of low-level affective responding is "The student is sensitive to the singing of birds" (p. 303). Others, though, are more controversial: "The student consistently prefers to study science over studying in other areas whenever he or she has a free choice" (p. 306). Is this to suggest that we should aim science instruction at having students take more science? Or again, "The student feels a sense of kinship with people who are scientists" (p. 303), and "The student changes his or her opinion on controversial issues when an examination of the evidence and the argument calls for revision of opinions previously held" (p. 311). It is not transparent that these are legitimate objectives of science education without some careful treatment of whatever relationships might exist between having a good understanding of science and liking scientists and between knowing how to behave within the discipline of science and making personal choices on controversial issues. Part of the problem here may be a direct descendant of the wedge that has been driven to separate the cognitive from the affective domain so far as speaking about the outcomes of learning goes. The wedge is

manmade, however, and so we ought to ask if the affective domain itself is a useful basis upon which to construct a fresh analysis of the concept "attitude to science." It might be more useful to start with the view that whatever personal preferences and attitudes people might have, these ought to be formulated wisely and thus grow out of the knowledge and understanding of science which is the business of science education to foster.

All this directs us to the need for a reconceptualization of instruments such as the SAI. Given the issues that have been raised, it is becoming plain that such a reconceptualization will have to attend very closely to analytical and philosophical ways of looking at problems. At this point, then, our traditional psychometric approaches to determining validity, employing such devices as factor analysis, cluster analysis, and/or the multi-trait multi-method convergent and discriminant validity model, will have to be supplemented with approaches to studying the conceptual validity of an instrument with something similar to the clue structure introduced here. Since validity is largely a conceptual matter, no amount of empirical work can assure us that an instrument is valid unless the empirical work is married to some rigorous, disciplined, and logically consistent analytical work. Until such a methodology is employed, we can never have confidence in the attitude instruments we use nor in the data and findings they yield.

References

Allison, R. D. An investigation into the attitudes towards science of college chemistry students as a function of laboratory experience. Unpublished Ed.D. dissertation, University of Northern Colorado, 1972. (DAI, 33, 3422)

Boes, R. J. The relation of selected student characteristics to understanding of science. Unpublished Ph.D. dissertation, University of Iowa, 1973. (DAI, 34, 4021)

Bowles, A., & Boss, M. W. Extent of psychological differentiation as related to achievement in science and attitude toward science. (ERIC Document Reproduction Service No. ED 087 978, 1974)

Brown, S. A. Affective objectives in an integrated curriculum. Unpublished Ph.D. dissertation, University of Stirling, 1975.

Buckley, J. T. A comparative study of the relationship of the presence of the elementary school science specialist toward the science attitudes of teachers and students and student achievement. Unpublished Ed.D. dissertation, Boston University, 1976. (DAI, 37, 1367)

Campbell, R. L., & Martinez-Perez, L. A. A study of relationships of science attitudes, achievement, and self-concept of pre-service teachers. (ERIC Document Reproduction Service No. ED 125 898, 1976)

Costa, J. J. A comparison of achievement and attitudes in college chemistry classes having direct laboratory, vicarious laboratory, or written descriptive narrative laboratory experiences. Unpublished Ed.D. dissertation, University of West Virginia, 1973. (DAI, 34, 3903)

Cummings, J. R. Development of an instrument to measure attitudes toward science and the scientist. Unpublished Ph.D. dissertation, Ohio State University, 1970. (DAI, 30, 2877)

Earl, R. D., & Winklejohn, D. R. Attitudes of elementary teachers toward science and science teaching. Science Education, 1977, 61, 41-45.

Gadson, M. F. A study of the effect of the thirteen-college curriculum program physical science course on the scientific attitude of college students. Unpublished Ed.D. dissertation, American University, 1976. (DAI, 37, 7056)

Gardner, P. L. Attitudes to science: A review. Studies in Science Education, 1975, 2, 1-41.

Geiger, M. M. A study of scientific attitudes among junior college students in Mississippi. Unpublished Ph.D. dissertation, University of Southern Mississippi, 1974. (DAI, 35, 5950)

Giese, R. N. An analysis of selected aspects of the ISCS model of science teaching. Part I: Relationships of selected characteristics and behaviors of teachers using the Intermediate Science Curriculum Study. Unpublished Ed.D. dissertation, Temple University, 1971. (DAI, 32, 4466)

Gunsch, L. M. A comparison of students' achievement and attitude changes resulting from a laboratory and non-laboratory approach to general education physical science courses. Unpublished Ed.D. dissertation, University of Northern Colorado, 1972. (DAI, 33, 6291)

Klopfer, L. E. A structure for the affective domain in relation to science education. Science Education, 1976, 60, 299-321.

Kozlow, M. J., & Nay, M. A. An approach to measuring scientific attitudes. Science Education, 1976, 60, 147-172.

LaShier, W. S., & Nieft, J. W. The effects of an individualized, self-paced science program on selected teacher, classroom and student variables--ISCS level one. Journal of Research in Science Teaching, 1975, 12, 359-369.

Lauridsen, L. I. An investigation of the effects of ISCS level one on selected affective variables of students. Unpublished Ed.D. dissertation, University of Kansas, 1972. (DAI, 33, 6747)

Lawrenz, F. The relationship between science teacher characteristics and student achievement and attitude. Journal of Research in Science Teaching, 1975, 12, 433-437.

Lawrenz, F. The prediction of student attitude toward science from student perception of the classroom learning environment. Journal of Research in Science Teaching, 1976, 13, 509-515.

Likert, R. The method of constructing an attitude scale. In M. Fishbein (Ed.), Readings in attitude theory and measurement. New York: John Wiley, 1967.

Lucas, D. H. The effect that participation in an instructional program at Fernbank Science Center has on upper elementary school students' scientific attitudes. Unpublished Ph.D. dissertation, Georgia State University, 1974. (DAI, 35, 6530)

Martin, B. R. A study of the effect of the blue, green, and yellow versions of BSCS biology on the scientific attitude of tenth-grade students. Unpublished Ed.D. dissertation, The American University, 1972. (DAI, 33, 2079)

Martinez-Perez, L. A. A study of self-concept, attitudes toward science and achievement on a sample of seventh-grade ISCS students versus seventh-grade students in a non-individualized science class. Unpublished Ph.D. dissertation, Florida State University, 1973. (DAI, 34, 4029)

McDuffie, T. E., Jr. Relationships between selected personal characteristics and achievement, attitude and success on an audio-tutorial biology program. Unpublished Ed.D. dissertation, Temple University, 1973. (DAI, 34, 1729)

Meyers, C. E. What I like to do: An inventory of students' interests. Chicago, Ill.: Science Research Associates, 1975.

Moore, R. W. A profile of the scientific attitudes of 672 ninth-grade students. School Science and Mathematics, 1971, 71, 229-232.

Moore, R. W. A two-year study of a CCSS group's attitudes toward science and science teaching. School Science and Mathematics, 1975, 75, 288-290.

Moore, R. W., & Sutman, F. X. The development, field test and validation of an inventory of scientific attitudes. Journal of Research in Science Teaching, 1970, 7, 85-94.

Munby, H. The provision made for selected intellectual consequences by science teaching: Derivation and application of an analytical scheme. Unpublished Ph.D. dissertation, University of Toronto, 1973. (DAI, 34, 6364)

Munby, H. Some implications of language in science education. Science Education, 1976, 60, 115-124.

Munby, H. An investigation into the measurement of attitudes in science education. Kingston, Ontario: Faculty of Education, Queen's University, 1979. (mimeographed)

Munby, H. An evaluation of instruments which measure attitudes to science. In C. P. McFadden (Ed.), World trends in science education. Halifax, Nova Scotia: The Atlantic Institute of Education, 1980.

Munby, H., Orpwood, G., & Russell, T. (Eds.). Seeing curriculum in a new light: Essays from science education. Toronto, Ontario: OISE Press, 1980.

Munby, H., & Wilson, R. Convergent and discriminant validity of classroom observation instruments: Conceptual background, critique, and a case in point. Alberta Journal of Educational Research, 1978, 24, 69-80.

Myers, B. E. An appraisal of change of attitudes toward science and scientists and of student achievement in an introductory college chemistry course relative to the students' backgrounds in high school chemistry and physics. Unpublished Ed.D. dissertation, Pennsylvania State University, 1967. (DAI, [illegible], 152)

Nagel, E. The structure of science: Problems in the logic of scientific explanation. New York: Harcourt, Brace & World, 1961.

Nagy, P. Subtest formation by cluster analysis of the Scientific Attitude Inventory. Journal of Research in Science Teaching, 1978, 15, 355-360.

Novick, S., & Duvdvani, D. The relationship between school and student variables and the attitudes toward science of tenth-grade students in Israel. Journal of Research in Science Teaching, 1976, 13, 259-265. (a)

Novick, S., & Duvdvani, D. The scientific attitudes of tenth-grade students in Israel as measured by the Scientific Attitude Inventory. School Science and Mathematics, 1976, 76, 9-14. (b)

Pinkall, J. E. A study of the effects of a teacher inservice education program on fifth-grade and sixth-grade teachers and the students whom they teach in their knowledge of scientific processes, scientific content and attitude toward science and scientists. Unpublished Ed.D. dissertation, University of Nebraska, 1973. (DAI, 34, 7608)

Popowicz, L. A. Interdisciplinary approach to biology integrated with art: A vehicle for changing attitudes toward science. Unpublished Ph.D. dissertation, Boston College, 1975. (DAI, 35, 7143)

Redford, E. G. Attitudes toward science and science teaching. In V. J. Mayer (Ed.), Unpublished evaluation instruments in science education: A handbook. Columbus, Ohio: ERIC Information Analysis Center, 1974.

Riley, J. P. Effect of science process training on preservice elementary teachers' process skill abilities, understanding of science and attitudes toward science and science teaching. Paper presented at the annual meeting of the National Association for Research in Science Teaching, Los Angeles, 1975.

Roberts, D. A., & Russell, T. L. An alternative approach to science education research: Drawing from philosophical analysis to examine practice. Curriculum Theory Network, 1975, 5, 107-125.

Ward, W. H., Jr. A test of the association of class size to students' attitudes toward science. Journal of Research in Science Teaching, 1976, 13, 137-143.

Welch, W. W. Evaluation of the PSNS course, II: Results. Journal of Research in Science Teaching, 1972, 9, 147-156.

Wilson, J. Language and the pursuit of truth. Cambridge: Cambridge University Press, 1967.

Wilson, R. L. An evaluation of the use of an anthology of articles on the understanding of science selected to improve student attitudes toward science. Unpublished Ph.D. dissertation, University of Iowa, 1975. (DAI, 36, 7973)

Appendix

Items of the Scientific Attitude Inventory

1. I would enjoy studying science and using this knowledge in some scientific field.

2. Anything we need to know can be found out through science.

3. Scientific explanations can be made only by scientists.

4. Once they have developed a good theory, scientists must stick together to prevent others from saying it is wrong.

5. It is useless to listen to a new idea unless everybody agrees with the idea.

6. Science may be described as being primarily an idea-generating activity.

7. Scientists are always interested in improving their explanations of natural events.

8. If one scientist says a theory is true, all other scientists will believe him.

9. Science is so difficult that only highly trained scientists can understand it.

10. A useful scientific theory may not be entirely correct, but it is the best idea scientists have been able to think up.

11. We can always get answers to our questions by asking a scientist.

12. There are some things which are known by science to be absolutely true.

13. Most people are not able to understand the work of science.

14. Today's electric appliances are examples of the really valuable products of science.

15. Scientists cannot always find the answers to their questions.

16. When something is explained well, there is no reason to look for another explanation.

17. Most people are able to understand the work of science.

18. A scientific theory is no better than the objective observations upon which it is based.

19. Scientists believe that they an find explanations for what they observe by looking at natural phenomena.

20. The day after day search for scientific knowledge would become boring for me.

21. Scientific work would be too hard for me.

22. Scientists discover laws which tell us exactly what is going on in nature.

23. Scientific ideas may be said to undergo a process of evolution in their development.

24. The value of science lies in its usefulness in solving practical problems.

25. When one asks questions in science, he gets information by observing natural phenomena.

26. A good scientist doesn't have any ideas he is not willing to change.

27. Looking at natural phenomena is a most important source of scientific information.

28. Public understanding of science is necessary because scientific research requires financial support through the government.

29. Some questions cannot be answered by science.

30. Rapid progress in science requires public support.

31. Scientists do not need public support; they can get along quite well without it.

32. A scientist must be imaginative in developing ideas which explain natural events.

33. The value of science lies in its theoretical products.

34. Ideas are one of the more important products of science.

35. I do not want to be a scientist because it takes too much education.

36. There is no need for the public to understand science in order for scientific progress to occur.

37. When a scientist is shown enough evidence that one of his ideas is a poor one, he should change his idea.

38. All one has to do to learn to work in a scientific manner is to study the writings of great scientists.

39. Before one can do anything in science, he must study the writings of the great scientists.

40. People need to understand the nature of science because it has such a great effect upon their lives.

41. A major purpose of science is to produce new drugs and save lives.

42. One of the most important jobs of a scientist is to report exactly what his senses tell him.

43. If a scientist cannot answer a question, all he has to do is to ask another scientist.

44. An important purpose of science is to help man to live longer.

45. I would enjoy working with other scientists in an effort to solve scientific problems.

46. Scientific laws cannot be changed.

47. Science is devoted to describing how things happen.

48. Every citizen should understand science because we are living in an age of science.

49. I may not make many great discoveries, but working in science would still be interesting to me.

50. A major purpose of science is to help man live more comfortably.

51. Scientists should not criticize each other's work.

52. His senses are one of the most important tools a scientist has.

53. Scientists believe that nothing is known to be true with absolute certainty.

54. Scientific laws have been proven beyond all possible doubt.

55. I would like to work in a scientific field.

56. A new theory may be accepted when it can be shown to explain things as well as another theory.

57. Scientists do not have enough time for their families or for fun.

58. The products of scientific work are mainly useful to scientists; they are not very useful to the average person.

59. Scientists have to study too much and I would not want to be one for this reason.

60. Working in a laboratory would be an interesting way to earn a living.